

CONTROLLED MESH ENRICHMENTS FOR EVOLVING GEOMETRIES

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In evolving geometry problems, such as the finite element simulations of 3D metal forming processes, the workpiece undergoes large plastic deformation. This leads to severe mesh distortions on the workpiece mesh after some incremental steps. In order to continue the simulation and/or keep the solution accuracy high, the mesh of the workpiece needs to be maintained properly so that the mesh-associated errors are kept within prescribed limits. 3D metal forming simulations conducted by DEFORM [1] as a FEM engine are automated by applying an adaptive mesh control whenever mesh needs to be improved. In the adaptive mesh control procedure, local mesh modifications are used, which facilitated performing mesh enrichments on only desired portions of the mesh. Applying local mesh modifications saved a significant amount of computational work in the mesh enrichment processes. The adaptive mesh control reflected the gradation effects of the state variables on the workpiece mesh through an a posteriori error estimator. The transfer of history-dependent state variables is also accounted for through integration with the local mesh modification operators. The transfer of state variables locally from old to new configurations of the mesh eliminated the assembly of big matrices and storage of a copy of the old mesh, which is the common trend in global operations.

Mesh discretization errors are controlled by using an h-adaptive procedure. An error estimator, developed by Zienkiewicz and Zhu [2], is adopted, and a consecutive adaptive analysis is conducted. In the adaptive mesh enrichments, a mesh size field, computed based on the allowed error tolerance, is used. Post-processing is applied on the mesh size field to control penetration issues and mesh gradation around small geometric features. In adaptive mesh control, entity splitting and collapsing operations are used for refinement and coarsening processes, respectively. Element distortion errors, due to the large deformations on the finite elements, and geometric approximation errors, due to the discretization of the workpiece geometry, are also accounted for in the mesh enrichment process. The mesh model, which is constructed based on workpiece boundary conditions, is maintained accurately and efficiently by considering volume, contact surface conservation and penetration control. Element shape improvements are applied to poorly shaped elements to increase their quality to desired level.

Example simulations are investigated. Adaptive mesh control of the workpiece is compared with a global remeshing procedure. The results of the simulations are assessed by studying the element quality in the meshes, mesh density distribution, load-stroke curves, local solution transfer accuracy, etc. Also, some comparisons, based on the size of the workpiece mesh and the time spent for adaptive mesh control, are presented to investigate the efficiency of the automated code. Finite element meshes of some simulations will be presented in incremental order to demonstrate the effects of the adaptive mesh enrichments applied.

References

- [1] DEFORMTM User Manual, SFTC, 2002.
- [2] O. C. Zienkiewicz and J. Z. Zhu, "The Superconvergent Patch Recovery and A Posteriori Error Estimates. Part 1: The Recovery Technique" *International Journal for Numerical Methods in Engineering*, v. 33, p. 1331-1364, 1992.